STUDENT GUIDE
EXPLORE 2 LESSON 10

Food and Agriculture Center for Science Education

Part 1: Our Motivation

Record what we were trying to figure out that led to this investigation.

At the end of Lesson 9, we realize that CO_2 and methane have increased in the atmosphere since the Industrial Revolution because of human activities. Cow burps have played a part, but they seem to be a small part.

Questions that led to this investigation are:

- Which contributes more to greenhouse gases in the atmosphere: human activities or cow burps?
- How is the greenhouse effect different for carbon dioxide and methane in the atmosphere?
- Which is worse for the atmosphere, carbon dioxide or methane?

Part 2: Analyzing Greenhouse Gas Residence Time

Below is a data table that lists greenhouse gases and the amount of time they spend in the atmosphere, which is also known as residence time.

Greenhouse gas	Average lifetime in the atmosphere
Carbon dioxide	50-200 years*
Methane	12 years

Content modified from : https://www.icsusa.org/pages/articles/2010-icsusa-articles/november-2010---carbon-dioxide-the-800-pound-gorilla-that-we-have-to-talk-about.php

Analyze the data from the table above and compare the residence time and global warming potential of methane to that of other greenhouse gases.

Methane has the shortest lifetime in the atmosphere of 12 years. Carbon dioxide spends much more time in the atmosphere, at 50-200 years.

After looking at data about residence time for greenhouse gases, what new questions do you have? Write these in the space below.

- Why does CO_2 stay in the atmosphere longer than methane?
- Where do the gases go if they do not stay in the atmosphere?

Part 3: Using a Model to Investigate Movement of Methane and Carbon Dioxide

In the space below, describe where you find carbon, how you think carbon moves in the environment, and the various forms that carbon takes on as it moves.

Carbon is a chemical element (atom) that is the building block of life. It connects with other atoms of itself to form "molecules" and "compounds." It can be found in the Earth's atmosphere, soil, oceans/water bodies, and rocks on Earth's surface. It can take the form of a solid, liquid, or gas as it moves through what is known as the carbon cycle. Carbon is stored in pools (aka stocks or reservoirs). Carbon moves through the carbon cycle from one pool to another through specific mechanisms. The transfer of carbon from one pool to another is called carbon flow or flux.

Journey – Fossil Fuel Emissions

1. Around the room, there are stations that represent carbon pools that are part of the Carbon Travel Game. In this game, you will model how molecules containing carbon, such as methane and carbon dioxide, move into and out of the atmosphere.
2. Move to the starting station as instructed by your teacher. Working with a partner, follow the instructions on each of the station cards to determine where your carbon molecule moves.
3. Record this step of your carbon journey in the table below.
4. You must complete 10 turns. Record your data in the table on the next page.
5. After you are finished, draw arrows representing your movement from one carbon pool to another on the class model on the board.

Journey – Cow Burps and Methane

6. Repeat the game by following the instructions on each of the station cards for methane. You must complete 10 turns. Record your data in the table on the following pages.
7. After you are finished, use a different color to draw arrows on the class carbon cycle to represent your movement through the carbon cycle as methane.

Complete the table below as you work through each station.

Journey – Fossil Fuel Emissions			
Number Rolled	**Where is carbon now?** *List the pool where you currently reside*	**Through what process did carbon leave?** *List the flow or process to take you to another pool*	**Where did carbon arrive?** *List the pool where you move to*
1	Fossil Fuel Deposits as carbon	Stay as carbon in Fossil Fuel Deposits	Fossil Fuel Deposits as carbon
5	Fossil Fuel Deposits as carbon	Extracted and burned in a car or power plant and converted into CO_2	Atmosphere as CO_2
2	Atmosphere as CO_2	Take up by plant as part of photosynthesis and synthesized into sugar or longer carbon chain	Terrestrial Life as sugar or longer carbon chain
5	Terrestrial Life as sugar or longer carbon chain	The organism you were part of died and now it has decayed in the ground	Soil as carbon
3	Soil as carbon	Stay in soil as carbon	Soil as carbon

Journey – Fossil Fuel Emissions (continued)			
Number Rolled	**Where is carbon now?** *List the pool where you currently reside*	**Through what process did carbon leave?** *List the flow or process to take you to another pool*	**Where did carbon arrive?** *List the pool where you move to*
6	Soil as carbon	Chain decayed and became CO_2	Atmosphere as CO_2
1	Atmosphere as CO_2	Stay in atmosphere as CO_2	Atmosphere as CO_2
6	Atmosphere as CO_2	Dissolved into Surface Ocean as CO_2	Surface Ocean as CO_2
3	Surface Ocean as CO_2	Through wave action, come out of solution as CO_2	Atmosphere as CO_2
4	Atmosphere as CO_2	Dissolved into Surface Ocean as CO_2	Surface Ocean as CO_2

Complete the table below as you work through each station card.

Journey – Cow Burps and Methane			
Number Rolled	**Where is carbon now?** *List the pool where you currently reside*	**Through what process did carbon leave?** *List the flow or process to take you to another pool*	**Where did carbon arrive?** *List the pool where you move to*
6	Terrestrial Life as a carbon chain in plant cellulose	Decayed plant matter as carbon	Soil as carbon
4	Soil as carbon	Stay as soil carbon	Soil as carbon
2	Soil as carbon	Stay as soil carbon	Soil as carbon
5	Soil as carbon	Oxidized by soil microbes and released at soil surface	Atmosphere as CH_4
4	Atmosphere as CH_4	Converted into CO_2 by hydroxyl oxidation and taken up by a plant	Terrestrial Life as CO_2

Journey – Cow Burps and Methane (continued)			
Number Rolled	**Where is carbon now?** *List the pool where you currently reside*	**Through what process did carbon leave?** *List the flow or process to take you to another pool*	**Where did carbon arrive?** *List the pool where you move to*
1	Terrestrial Life as CO_2	Eaten by grazing cow and converted into CH_4 through digestion	Atmosphere - Methane as CH_4
6	Atmosphere - Methane as CH_4	Converted into CO_2 by hydroxyl oxidation and dissolved into water	Surface Ocean as CO_2
1	Surface Ocean as CO_2	Stay as dissolved CO_2	Surface Ocean as CO_2
2	Surface Ocean as CO_2	Through wave action, come out as CO_2	Atmosphere - Carbon Dioxide as CO_2
5	Atmosphere - Carbon Dioxide as CO_2	CO_2 dissolves into water	Surface Ocean as CO_2

Part 4: Using a Model to Explain Residence Times and Greenhouse Effect for Carbon Dioxide and Methane

In the space below, explain why methane and carbon dioxide have different residence times in the atmosphere.

Carbon Dioxide	Methane
The burning of fossil fuels greatly increased movement of carbon into the atmosphere since industrialization. This has resulted in CO_2 building up in the atmosphere because the flux of carbon from fossil fuels to the atmosphere is larger than the flux of carbon dioxide out of the atmosphere. It also has a long residence time (anywhere from 50 to 200 years).	Methane does not stay in the atmosphere as long as carbon dioxide (only 12 years residence time) because it gets transformed into carbon dioxide and then moves to other carbon pools. We can see that the flux of methane into the atmosphere is about the same as the fluxes that take methane out of the atmosphere.